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Precision Flyer Initiator

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The Precision Flyer Initiator[2] (PFI) was developed to provide a precisely centered and spherical detonation wave breakout from any initiation driver source including common detonators, exploding foils or cord detonators. The PFI concept is that a flyer may be launched by any drive source of sufficient energy to initiate the HE pellet on impact. The centering of the breakout depends on the geometry of the barrel and gap and the precision of their placement with respect to the pellet. The sphericity of the breakout depends on the diameter of the flyer and the uniformity of the pressing of the pellet. A gap between the barrel and the pellet is essential to prevent the shock in the barrel from initiation the HE before the arrival of the flyer.

The LLNL Micro Detonics Facility (μDF)[3] was used to dynamically measure the breakouts of several PICs and the PFIs. The facility was established at Lawrence Livermore National Laboratory for small and micro scale studies of detonation and shock wave phenomena. To measure detonation breakout, a mirror surface was placed in contact with the HE. The mirror is viewed by specular reflection at normal incidence. If the mirror coating is thin, ≤0.1μm, then the disruption of the specular reflectivity is a good indicator of the passage of the detonation wave. The diagnostics used were the Nanosecond Micro-Frame and the Micro Streak cameras in a confocal epi-polarizing microscope configuration (Figure 1). Illumination for the frame camera was a 1ns pulsed dye laser focused to uniformly cover the 6mm pellet. For the streak camera a CW argon laser was focused to a line across the pellet. Illumination was incident on the pellet, coaxially with the viewing microscope. A quarter wave plate and polarizer were used to separate the illumination and image beams. A common objective lens was used for both the frame and streak cameras as well as the final focusing element of the illumination. The objective is a large format camera lens used backwards as a long working distance microscope. A working distance of greater than 75mm is required to view the target through a protective window into the HE chamber. A polarizing beam splitter separates the frame and streak images. A half wave plate is used to adjust the illumination ratio to the cameras. Magnifications from the object to the film plane for these experiments were 3X for the streak camera and 10X for the frame camera. A 75mm proximity focused diode, gated to 15ns, was used for the frame camera. The streak camera is a Hamamatsu C2780, with a large format tube. Resolution for both cameras was about 5μM over an 8mm field of view. Film (TMAX-400) was used as the recording medium for the cameras.

The initial PFI was developed for initiation of shaped charges requiring breakout sphericity better than was available with a bi-conical or hourglass Precision Initiation Component (PIC). The centering and sphericity of the PIC breakout is determined by the minimum constriction diameter. The minimum diameter is limited by the failure diameter of the explosive used. At diameters close to failure, the burn through the constriction is highly dependent on the pressing density. At larger diameters the sphericity is degraded and artifacts of the initiation propagate through the constriction. A series of hourglass shaped PICs was exhibiting intermittent failures and inconsistent performance. These devices have a 1mm constriction and were filled with PBXN-5 (HMX / Viton). The PIC images were recorded earlier viewing the self-illumination punching through a contacting mirror. The detonation wave breakout images indicated detonation failure through the center of the device (figure 2). This result lead to the conclusion that there was a radial density gradient through the constriction. The shape of a PIC almost guarantees a higher density through the center than at the walls thus detonation failure will first occur at the center.

A right circular cylindrical pellet is easier to press freer of density gradients than a PIC. However special care must be exercised to preserve a spherical breakout. Powder poured into a small pellet die will naturally mound in the center, resulting in a radial density gradient in the pressed pellet. Special care was taken to level the powder in the die before pressing the PFI pellets. LX-16 (PETN + OXY-461 binder {4%}) was used for the pellet material to provide a small failure diameter material. When used in a heated die, the binder provides some fluid flow reducing small density variations. Reducing the pressing density to 1.55 reduces the failure diameter and moves the response of the HE to a more linear region of the POP Plot further limiting the variation of detonation velocity with density. Precision pellets were tested for pressing uniformity by measuring the breakout flatness when initiated with a 6mm plane wave generator[4] (figure 3).

Small slappers are commonly used to initiate detonator pellets. With sufficient driving energy, slappers as small as .3mm reliably initiate PETN. The concept of the PFI (figure 4) is to provide a precisely located strong and dense barrel to define the trajectory of the flyer. A gap between the barrel and the pellet is necessary to isolate the barrel shock from the pellet (Figure 5). If the barrel is the same length or longer than its diameter and the space is smaller or equal to the barrel diameter, then the maximum position error of the flyer impact will be less than or equal to the barrel radius. This will be true no matter what the driver is or the direction of the driving shock.

Two PFI drivers were tested; they used a standard RP-2 detonator and Deta-Cord respectively. The direction of travel of the detonation wave in the cord was perpendicular to the axis of the PFI barrel. Both were developed for the initiation of shaped charges. No difference in performance was discernable between drivers, however, the poor timing characteristics of the cord precluded a breakout image. With the more accurate timing of the RP-2, capturing a breakout image was still not predictable because of the extremely high phase velocity of the breakout and the residual jitters of the detonation and microscope systems. Small irregularities observed in both the streak and frame images indicate residual small-scale density variations in the pellet (figure 6). Two barrel diameters, 1.0 and 0.5mm, were tested (Figure 7) with the RP-2 detonators. The 1mm barrel resulted in deviations of about 40ns from an ideal spherical breakout at the edge of the pellet. The breakout with the .5mm barrel was spherical to within the ±2ns noise of the experiment.

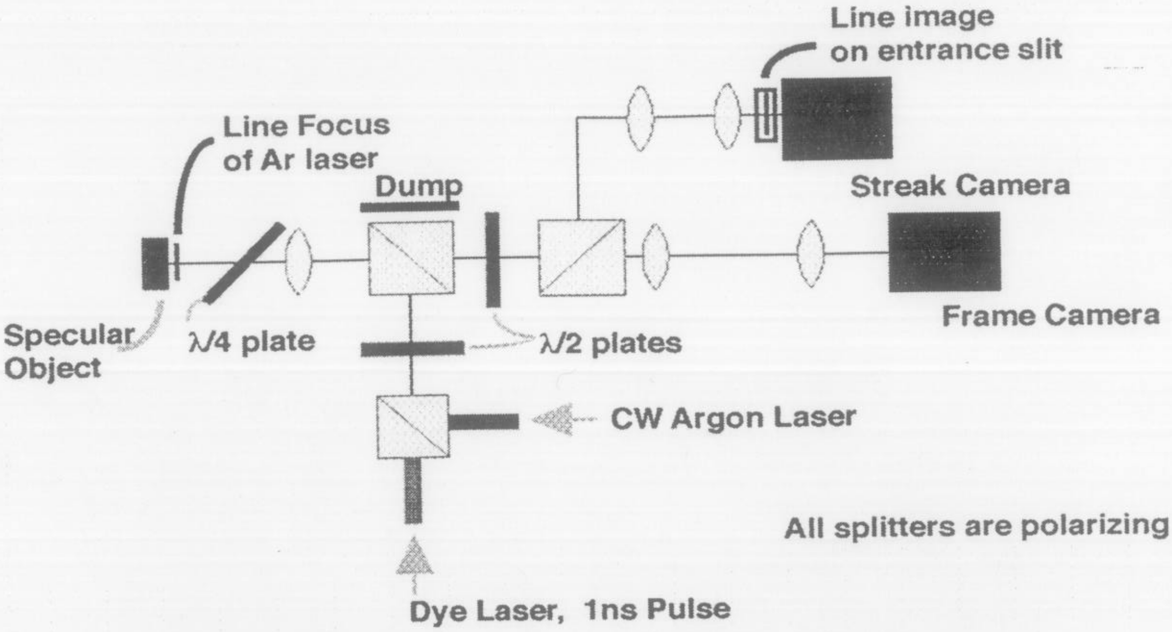

Figure 1, The microscope configuration used in testing the PFI.

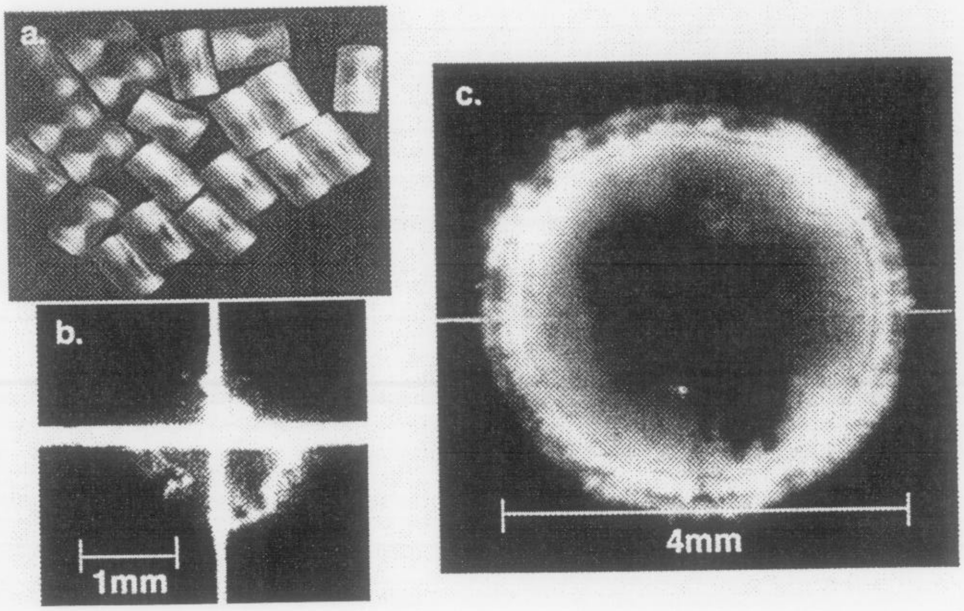

Figure 2, a) Photograph of the PIC's tested showing the hourglass shape of the HE within the PMMA bodies. b&c) Self lit images of the PIC shock waves breaking through a mirror surface. The reference marks were scribed in the mirror surface.

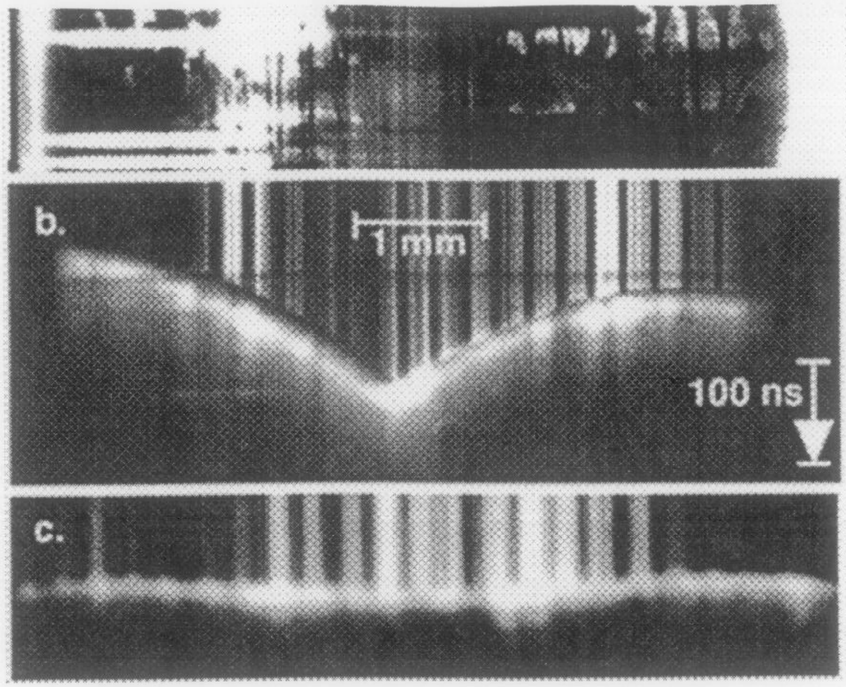

Figure 3) Streak images impacting mirror surfaces of; a) 6mm planar slapper initiator and detonation waves of, b) a normally pressed LX-16 Pellet and c) precision pressed LX-16 pellet.

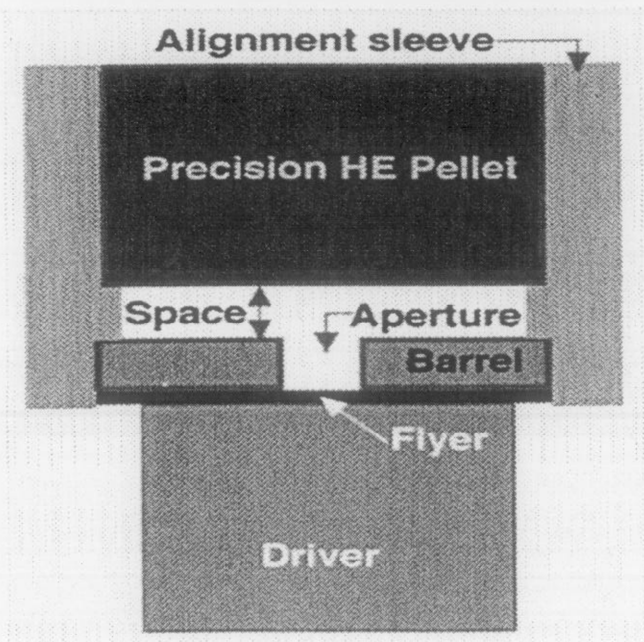

Figure 4) PFI Configuration

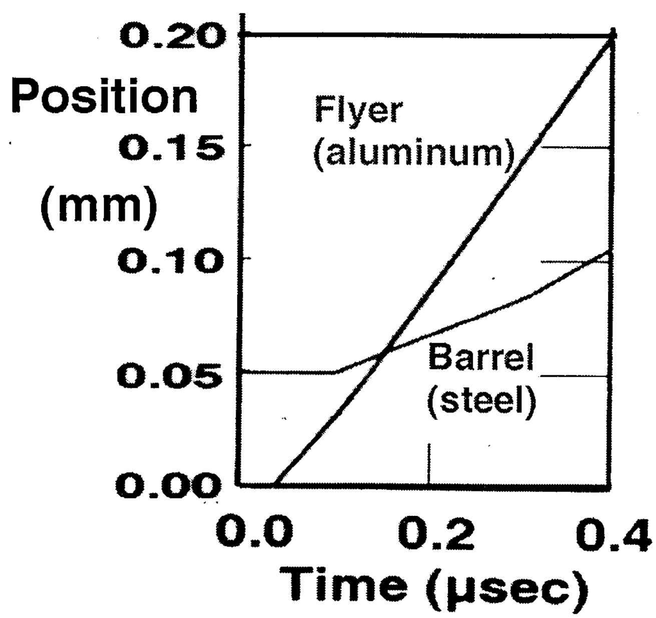

Figure 5) Computation of the relative position of the barrel and flyer faces after the arrival of the driver shock at the back of the flyer.

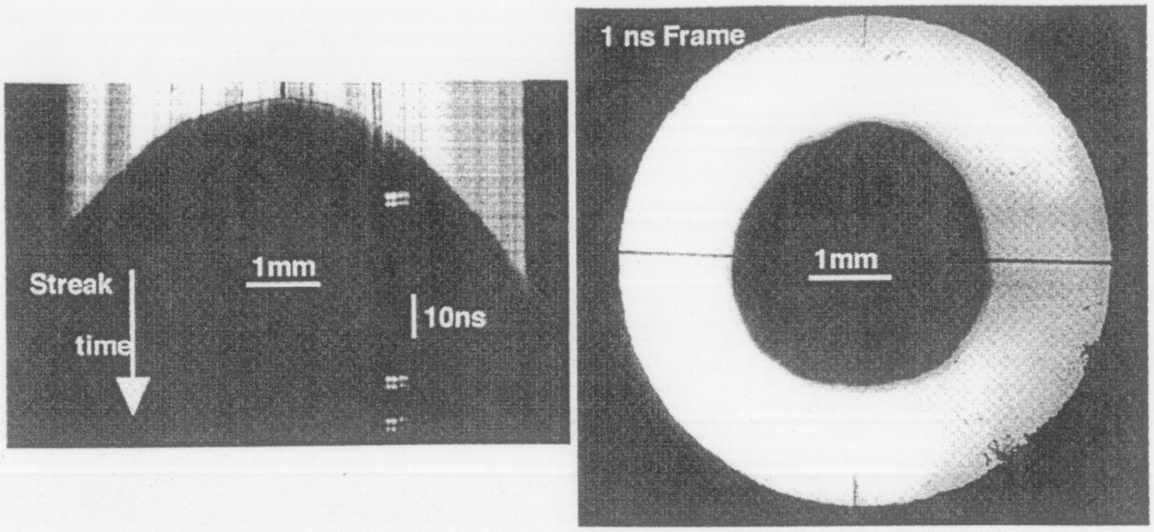

Figure 6) Streak and Frame images of PFI breakout through an illuminated mirror surface.

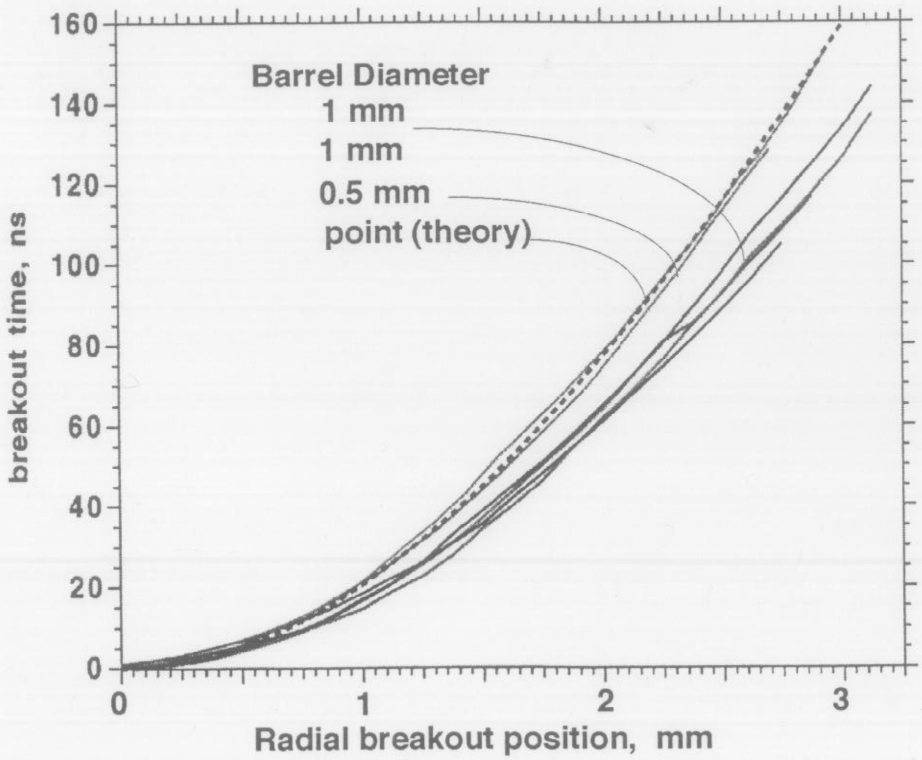

Figure 7) Measured PFI detonation wave breakout times as a function of radial position as compared to the theoretical curve from a point initiation.

[1] LLNL work under the auspices of the USDOE contract W-7405-ENG-48.
[2] Precision Flyer Initiator, U.S. Patent #5,756,925
[3] Frank A.M., "High Speed Microphotographic Laboratory", Proc 18th Int Congress, High Speed Photography & Photonics, Xian, China 1988
[4] Frank, A.M. & Chau, H.H., "Six-mm Plane Wave Shock Driver", APS Conference on High Pressure Science and Technology, Colorado Springs, CO, 1993